

Late Pleistocene Interstadial Environment on Faddeyevskiy Island, East-Siberian Sea, Russia

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Abstract

Pollen, plant macrofossil, loss-on-ignition and radiocarbon analyses of a 1.4-m section in thermokarst topography from Faddeyevskiy Island (75°20'N, 143°50'E, 30 m elevation) provides new information on Late Pleistocene interstadial environmental history of this high Arctic region. Conventional radiocarbon dates (25,700 ± 1000, 32,780 ± 500, 35,200 ± 650 yr BP) and two AMS dates (29,950 ± 660 and 42,990 ± 1280 yr BP) indicate that the deposits accumulated during the Kargian (Boutellier) interval. Numerous mammoth (*Mammuthus primigenius*) remains that have been collected in vicinity of the site in this study were radiocarbon dated to 36,700–18,500 yr BP. Rare bison (*Bison priscus*) bones were dated to 32,200 ± 600 and 33,100 ± 320 yr BP. Poaceae, Cyperaceae, and *Artemisia* pollen dominate the spectra with some Ranunculaceae, Caryophyllaceae, Rosaceae, and Asteraceae. The pollen spectra reflect steppe-like (tundra-steppe) vegetation, which was dominant on the exposed shelf of the Arctic Ocean. Numerous *Carex* macrofossils suggest that the summer climate was at least 2°C warmer than today. The productivity of the local vegetation during the Kargian interstadial was high enough to feed the population of grazing mammals.

Introduction

Paleoenvironmental records with associated chronology are rare in the East Siberian sector of the Arctic. Late Pleistocene and Holocene studies that were conducted on the Novosibirskiye Ostrova archipelago include those by Lozhkin (1977), Makeyev et al., (1989), and Alekseev (1989, 1997) on Kotel'nyy Island; by Verkulich et al., (1989) and Makeyev et al., (1992) on Bennett Island; by Pitul'ko and Makeyev (1991) and Pitul'ko (1993) on Zhokhov Island; by Kaplina and Lozhkin (1982), Lozhkin (1987), and Ukraintseva et al., (1989) on Bol'shoi Lyakhovskiy Island. However, there are no paleoenvironmental records with radiocarbon dates concerning the environmental changes on Faddeyevskiy Island during the Late Pleistocene and Holocene. Only one sample attributed to the Upper Pleistocene sediments was collected on Faddeyevskiy Island (Solov'ev and Stanisheva, 1983). It is difficult to draw conclusions about the age of deposits and the paleoenvironment, because the sample contains plant remains of *Azolla*, which belongs to a warm (possibly, Late Cretaceous) flora. Other plant remains from the sample could

also be reworked. Absence of dated Late Pleistocene and Holocene records from Faddeyevskiy Island led to suggestions that the island was submerged during the Late Pleistocene (Zagorskaya, 1959; Reinin and Kim, 1982) or under a major ice sheet (Grosswald, 1998). Our pollen, plant macrofossil, and radiocarbon analyses of a section from the central part of the island provide new information on the Late Pleistocene environmental history of this high arctic region.

Setting

Faddeyevskiy Island belongs to the Novosibirskiye Ostrova archipelago (Fig. 1). The island was discovered by Yakov San'nikov in 1805 and named in honor of Faddey, who was a pioneering hunter there. Faddeyevskiy Island is the name given the eastern part of the land, with the western montane portion called Kotel'nyy Island, and the central flat and low-elevation portion called Zemlya Bunge. Faddeyevskiy Island covers about 4000 km² with maximum elevation of about 61 m.

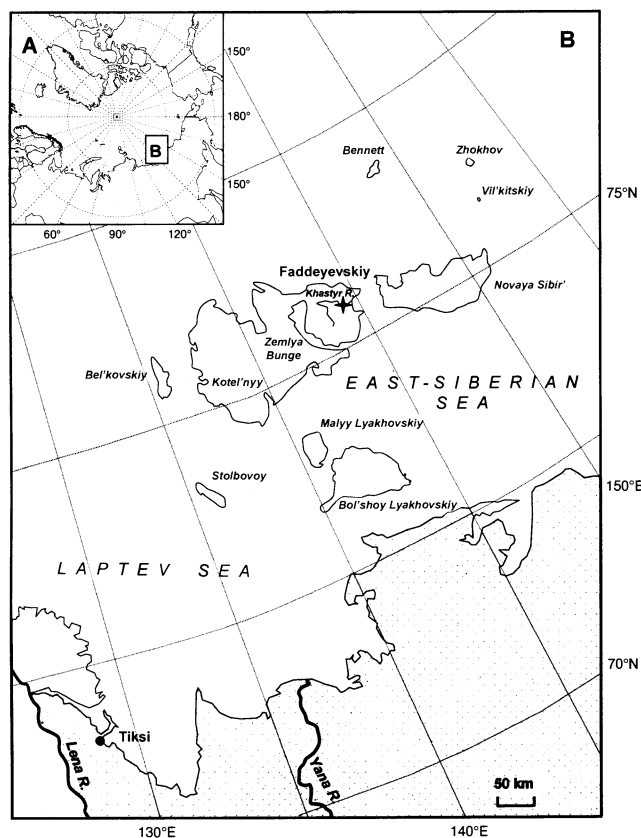


FIGURE 1. A map of the Arctic including our investigated site from Faddeyevskiy Island, Novosibirskiye Ostrova archipelago.

The Novosibirskiye Ostrova are in a Cretaceous tectonic depression and the total thickness of the Cretaceous deposits in the archipelago area is about 2 to 8 km (Zaitsev, 1989). The surface layer of deposits consists 400 to 500 m of Neogene-Pleistocene clayey and sandy marine, alluvial and lake sediments (Zaitsev, 1989).

According to *Geomorfologicheskoe raionirovanie* (1980) and *Atlas Arktiki* (1985) the central and southern parts of Faddeyevskiy Island are covered by late Pleistocene and Holocene marine, alluvial, and lake sediments. The northern part is covered by mid- and late Pleistocene deposits. The thickness of permafrost is about 400 to 500 m (Zaitsev et al., 1989). A plain, altered by thermokarst processes, characterizes the central part of the island. Deep erosive cuts are caused by intensive processes of ground ice melting. Numerous baidzarakhs (thermokarst mounds) are also notable in the landscape.

The investigated site (75°20'N, 143°50'E, 30 m elevation) on Faddeyevskiy Island (Fig. 1) was located in the middle part of the Khashtyr River valley. The upper part of the dark-gray icy, sandy, and clayey sediments (typical Yedoma ice complex) was exposed by thermokarst prior to the fieldwork in 1994.

Climate

Mean July temperature is about 2°C, mean January temperature is about -30 to -32°C, and mean annual temperature is about -15°C. The total annual precipitation is about 100 to 200 mm, with most of the precipitation falling during the summer. Snow thickness can be as much as 30 cm. The period without snow lasts about 3 mo and frost is present throughout the year. Easterly and south-easterly winds are predominant during the summer and southwest-erly winds during the winter (Doronina, 1963).

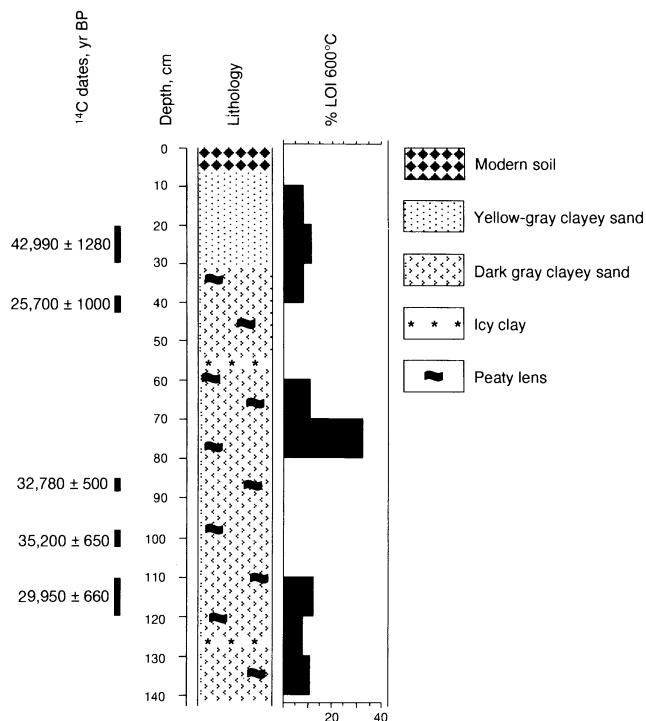


FIGURE 2. Lithology and percentages of Loss-on-ignition (LOI) at 600°C.

Vegetation

The vascular plant flora of Faddeyevskiy Island is very poor. Only 43 species have been recorded on the island (Mikhailov, 1963) and about 80 species have been recorded for the total archipelago (Korzhuev, 1965). The Novosibirskiye Ostrova archipelago belongs to the zone of high arctic tundra (Yurtsev, 1974; Aleksandrova, 1980). Moss-grass arctic tundra with grasses such as *Alopecurus alpinus* and *Poa alpigena* and mosses such as *Aulacomnium trigidum*, *Drepanocladus iniciatus*, *Rhacomitrium nugilosum*, *Batramia ithyphyda*, and *Ditrichum flexicauli* predominate. Moss-herb tundra with herbs such as *Saxifraga* (8 species), *Dryas octopetala*, *Potentilla emarginata*, *Ranunculus* (4 species), *Draba* (5 species), *Cerastium bialynskii*, *Papaver polare*, *Oxyria digyna*, *Salix polaris*, and mosses such as *Drepanocladus iniciatus*, *Rhacomitrium lanugilosum*, *R. canescens*, *Batramia ithyphyda*, *Hylocomium splendens*, *Dicranoweisia crispula*, and *Tomenthypnum noteus* extend throughout the island (Mikhailov, 1963).

Field and Laboratory Methods

A 1.4-m exposure in thermokarst topography containing lenses of plant macrofossils was selected for sampling. A monolith was collected by first cleaning with a shovel to expose frozen deposits, and by then cutting about 100-cc blocks of contiguous samples at 10-cm intervals and transferring them to sample bags. The samples were collected in the field by F. A. Romanenko. Unfortunately, sampling resolution was limited to the 10-cm interval. A total of 13 samples were collected for analysis of pollen and spores, plant macrofossils, loss-on-ignition, and radiocarbon dating.

Two methods of pollen preparation were used in order to compare the advantages and disadvantages of each method and to obtain as much information as possible. For both techniques pollen and spores were concentrated from 1-cm³ sediment subsamples, and

TABLE 1
Radiocarbon dates from the investigated site

Lab Number	Method	Depth (cm)	Sample Type	Age (yr BP)
ETH-18286	AMS	20–30	<i>Carex</i> seeds, twig	42,990 ± 1280
GIN-8283	Conventional	38.5–42.5	Unidentified macrofossils	25,700 ± 1000
GIN-8281	Conventional	85–88	Unidentified macrofossils	32,780 ± 500
GIN-8282	Conventional	98–103	Unidentified macrofossils	35,200 ± 650
ETH-17858	AMS	110–120	Two <i>Carex</i> seeds and wood pieces	29,950 ± 660

treated with 10% potassium hydroxide (KOH) to deflucculate humified sediments and with 10% hydrochloric acid (HCl) to remove calcareous sediments. A heavy liquid separation method (Berglund and Ralska-Jasiewiczowa, 1986) followed by acetolysis and glycerin mounts was used to process 13 samples in Petrozavodsk, Russia. We processed 8 of these 13 samples at Lamont-Doherty Earth Observatory, New York by a chemical digestion method (Faegri and Iversen, 1989). Unfortunately, the remaining 5 samples were lost in Moscow due to storage problems. Exotic *Lycopodium* tablets were added to the Lamont-Doherty Earth Observatory samples in order to calculate pollen influx.

Three to five hundred terrestrial pollen grains were counted for each sample at 400× magnification. Spores were counted in addition. Determination of relative frequency of pollen was calculated based upon the total pollen sum, and percentage of spores was based upon a sum of pollen and spores. Pollen concentration was calculated in the samples processed at Lamont-Doherty Earth Observatory using the method of Stockmarr (1971). The TILIA and TILIAGRAPH programs were originally used for the calculation of taxa percentages and graphing the data (Grimm, 1991). Then the original diagrams were redrawn

with PowerPoint software. Pollen zonation was done by visual inspection.

Loss-on-ignition (LOI) was measured in the eight samples following procedures outlined in Dean (1974). Macrofossils were also separated from same samples by soaking 50 cm³ of sediment overnight in 5% KOH, then washing with water through screens of 0.5-mm and 0.125-mm meshes. The constituent leaves, seeds, and other plant parts were stored in water and refrigerated. Macrofossil composition is shown per 50 cm³ of sample. Nomenclature for vascular plants follows Cherepanov (1981).

Handpicked, identified macrofossils were selected for AMS dating from 20–30 and 110–120 cm depth (Table 1). The samples for bulk ¹⁴C dating were collected separately from the section in the field (Table 1). The bulk radiocarbon measurements (conventional method) were conducted at the Laboratory for Isotope Geochemistry and Geochronology of the Geological Institute, Russian Academy of Science, Moscow and the AMS samples were dated at the Eidgenössische Technische Hochschule (ETH) AMS Laboratory, Zurich, Switzerland.

Results

RADIOCHRONOLOGY

Three bulk ¹⁴C dates and two AMS dates were obtained from the section (Table 1). While the bulk dates are in good sequence, the 20–30 cm AMS date is anomalous. This AMS date, 42,990 ± 1280 yr BP, from the 20–30 cm depth seems to be too old compared with the 29,950 ± 660 yr BP AMS date from 110–120 cm depth as well as the bulk data set. One possible explanation for the dates may be the reworked character of organic matter in the section. A twig used for this 20- to 30-cm sample could have been reworked at that depth, thus providing an older, inverted date for the sample. In contrast, the bulk radiocarbon dates are in good sequence. If these bulk ages all include a small size fraction of reworked older material, they would appear older than the AMS age of the 110–120 cm sample which dates to 29,950 ± 660 yr BP. Unfortunately, we cannot resolve the uncertainties between the AMS and the bulk dates, but as all ages date to the Kargian interstadial, 50,000–24,000 yr BP (Isaeva, 1984) we accept that interstadial designation for the section.

LOSS-ON-IGNITION AND LITHOLOGY

The loss-on-ignition diagram (Fig. 2) shows that the gray clayey-sandy and icy sediments (typical Yedoma ice complex) contain minimal organic material (up to 12%), except the sediments at 70–80 cm depth where organic content reaches 32%. The lowest 30–140 cm is dark gray clayey sand with numerous thin peaty lenses. Two thin, 3- to 5-cm, icy clay layers occur at the 50–60 cm and 120–130 cm depth. Between 5 and 30 cm depth lies yellow-gray clayey sand. The upper 5 cm of the section is modern soil with the local vegetation above.

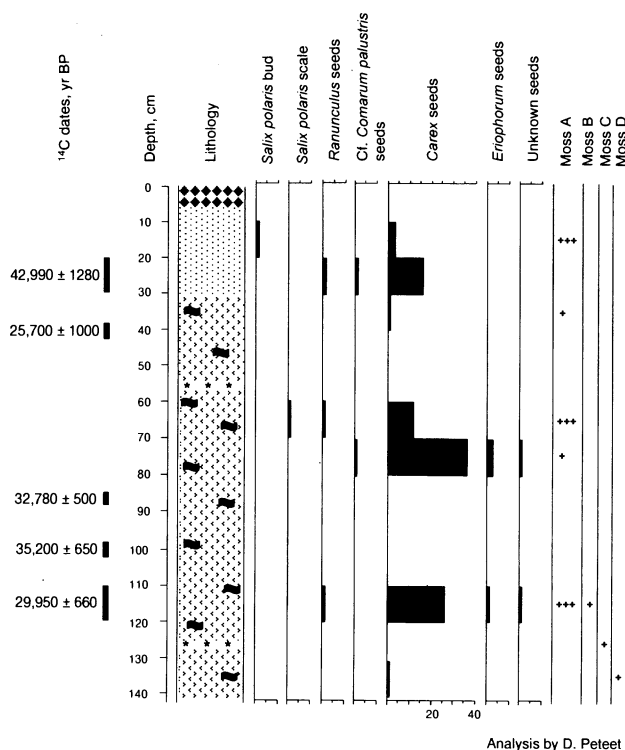


FIGURE 3. Macrofossil stratigraphy of investigated site. Amounts of vascular plant remains are shown in absolute counts. +—moss remains are rare, +++—moss remains are abundant. See Figure 2 for explanation of lithology.

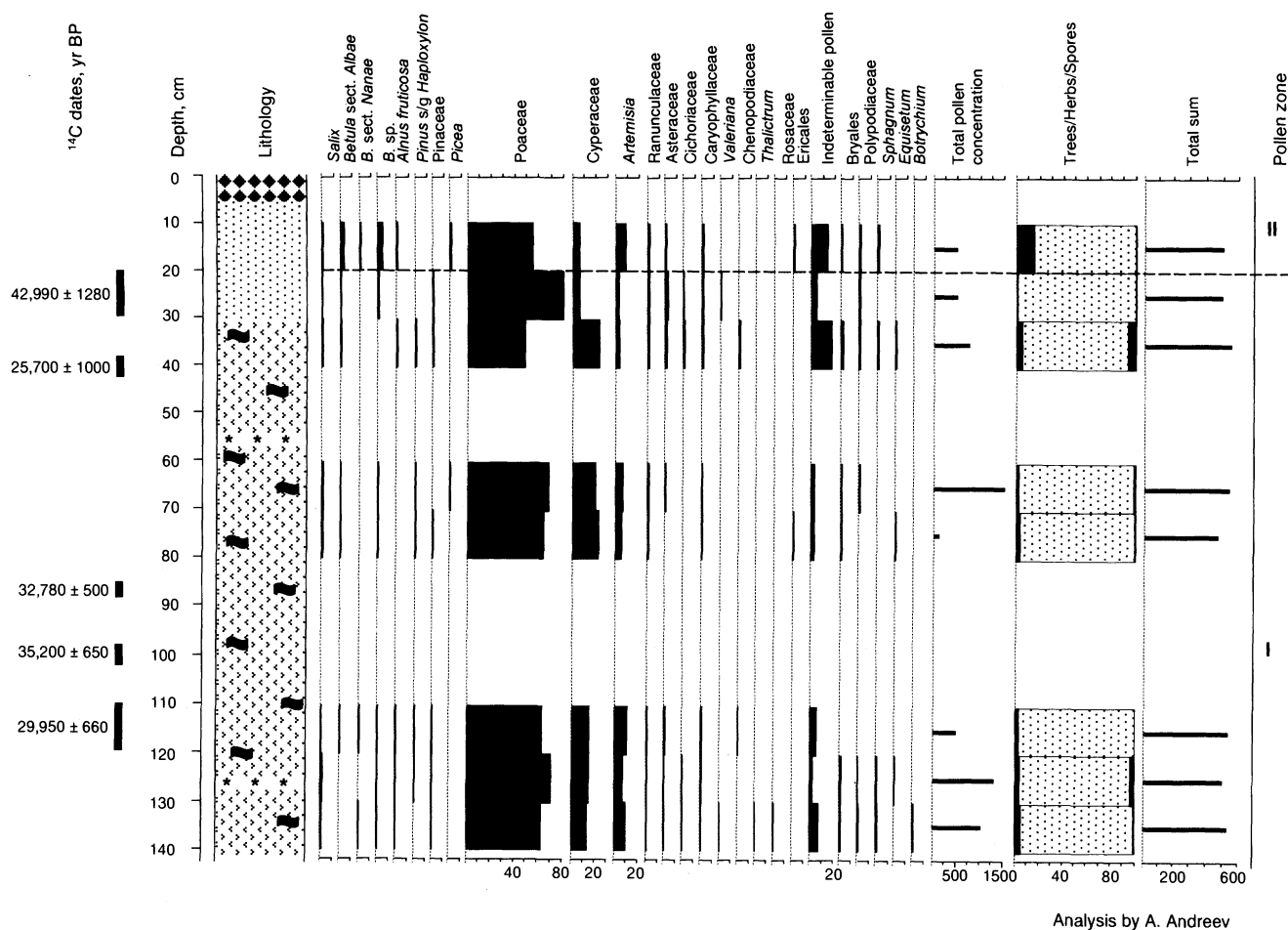


FIGURE 4. Pollen and spore stratigraphy of the investigated site (using the chemical digestion method). See Figure 2 for explanation of lithology.

PLANT MACROFOSSILS

Carex seeds and abundant moss provide the primary macrofossil component of the sediments (Fig. 3). *Eriophorum* seeds are also present in the lowermost sediments, while *Ranunculus* occurs throughout. *Salix polaris* buds occur in the upper portion of the section.

POLLEN STRATIGRAPHY

Two pollen zones were recognized (by the visual inspection) in both of the diagrams (Figs. 4, 5). In Figure 4, pollen zone I (140–20 cm) is notable for its large amounts of Poaceae (60–80%), Cyperaceae (0–20%) and *Artemisia* (10%) pollen. Figure 5 shows the same dominants in pollen percentages but with more variability, with Poaceae ranging from 30–80%, Cyperaceae ranging from 20–60%, and *Artemisia* ranging from 0–10%.

Pollen zone II (20–0 cm) is characterized by the significant increase of long-distance transported tree pollen (from less than 2% up to 10%) in both diagrams such as *Picea* (3%), *Betula* sect. *Albae* (10%), *Alnus* (3%), and the appearance of *Ericales* (2%), although Poaceae (30–50%), Cyperaceae (10–20%), and *Artemisia* (10%) pollen continue to dominate the spectra.

Discussion

The sediment at 140–20 cm depth was deposited during the Late Pleistocene, between approximately 32,000 and 25,000 yr

BP according to the AMS and bulk ^{14}C dates. It appears that sedimentation at the site halted during late Kargian time or the subsequent beginning of the Last Glacial Maximum, possibly due to erosive winds. It is not clear if the thin peaty lenses (probably, peaty soil horizons) with numerous *Carex* seeds were originally situated in the clayey sand or if the material was transported from higher elevations nearby. However, the excellent preservation of plant remains suggests that even if the plant remains were redeposited they were transported for a very short distance only. The ordered sequence of bulk radiocarbon dates (Table 1) allows us to infer that the peaty lenses and clayey sediments have approximately the same age.

Pollen Zone I suggests a tundra-steppe environment. In both pollen diagrams Poaceae pollen dominates the pollen spectra, with some Cyperaceae, *Artemisia*, and few Rosaceae, Caryophyllaceae, Ranunculaceae, and other herbs (Figs. 4, 5). The existence of tundra-steppe in northern Eurasia and the definition of this term are discussed by previous investigators (Kozhevnikov and Ukrantseva, 1997), but we use the term to describe low herb vegetation with some tundra species in wetter places and steppic species in drier places. We assume that our pollen spectra reflect a combination of graminoid and *Artemisia* dominated, steppe-like associations with tundra associations in the vegetation.

The pollen spectra of the upper 20 cm of the yellow-gray sands with low pollen concentration (Fig. 4, 5) show an increase in the contents of long-distance transported pollen such as *Picea*, *Betula*, *Alnus*, *Pinus*, and *Ericales*, although Cyperaceae, Poaceae, *Artemisia*, and other herbs pollen dominate the spectra.

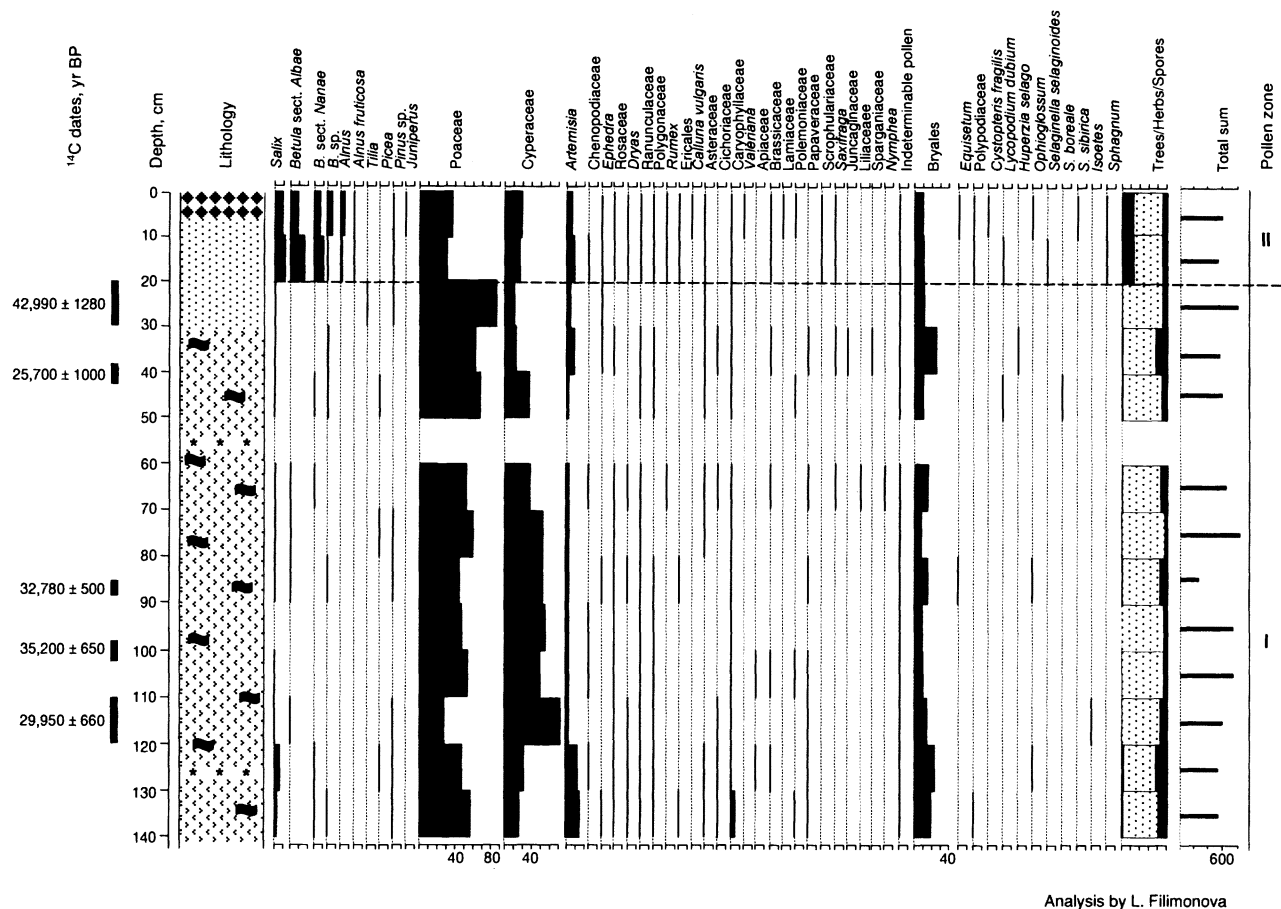


FIGURE 5. Pollen and spore stratigraphy of the investigated site (using the heavy liquid separation method). See Figure 2 for explanation of lithology.

TABLE 2
Radiocarbon dates of Kargian ages from Siberia

Location	Lab Number	Age (yr BP)	Source
West Siberia	SOAN-974	29,500 ± 520	Arkhipov (1984)
West Siberia	SOAN-671	25,900 ± 900	Arkhipov (1984)
Central Siberia	GIN-987	36,700 ± 1000	Isayeva (1984)
Central Siberia	GIN-823	36,260 ± 1000	Isayeva (1984)
Central Siberia	GIN-986	35,000 ± 500	Isayeva (1984)
Central Siberia	GIN-984	28,400 ± 1500	Isayeva (1984)
Central Siberia	GIN-1156	28,300 ± 1200	Isayeva (1984)
Central Siberia	GIN-968	26,400 ± 1000	Isayeva (1984)
Central Siberia	GIN-989	23,800 ± 500	Isayeva (1984)
Northern Yakutia	MAG-499	38,000 ± 800	Lozhkin (1987)
Northern Yakutia	MAG-802	38,000 ± 1000	Lozhkin (1987)
Northern Yakutia	MAG-494	36,200 ± 600	Lozhkin (1987)
Northern Yakutia	MAG-497	36,000 ± 650	Lozhkin (1987)
Northern Yakutia	MAG-803	35,000 ± 1000	Lozhkin (1987)
Northern Yakutia	MAG-801	34,500 ± 500	Lozhkin (1987)
Northern Yakutia	MAG-805	31,400 ± 500	Lozhkin (1987)
Northern Yakutia	MAG-425	31,000 ± 1000	Lozhkin (1987)
Northern Yakutia	MAG-660	30,600 ± 600	Lozhkin (1987)
Northern Yakutia	MAG-506	29,800 ± 700	Lozhkin (1987)
Northern Yakutia	MAG-503	28,700 ± 2000	Lozhkin (1987)
Northern Yakutia	GIN-2396	28,100 ± 1000	Kaplina and Giterman (1983)
Northern Yakutia	MAG-109	27,860 ± 450	Lozhkin (1987)
Northern Yakutia	MAG-153	26,950 ± 330	Lozhkin (1987)
Northern Yakutia	MAG-160	24,550 ± 260	Lozhkin (1987)
Chukcha Peninsula	MAG-678	30,600 ± 900	Ivanov et al. (1984)
Chukcha Peninsula	MAG-674	28,900 ± 260	Ivanov et al. (1984)

TABLE 3
Radiocarbon dated Mammuthus primigenius remains from Novosibirskie Islands

Location	Lab Number	Age (Yr BP)	Source
Faddeyevskiy	GIN-8243a	36,700 ± 500	Sulerzhitsky and Romanenko (1997)
Faddeyevskiy	GIN-8238	36,000 ± 500	Sulerzhitsky and Romanenko (1997)
Bel'kovskiy	GIN-8223	35,800 ± 700	Sulerzhitsky and Romanenko (1997)
Faddeyevskiy	GIN-8243	35,210 ± 500	Sulerzhitsky and Romanenko (1997)
Faddeyevskiy	GIN-8247	34,500 ± 500	Sulerzhitsky and Romanenko (1997)
Kotel'nyy	GIN-8254	34,400 ± 400	Sulerzhitsky and Romanenko (1997)
B. Lyakhovskiy	MAG-316	32,100 ± 900	Lozhkin (1987)
B. Lyakhovskiy	MAG-316A	32,030 ± 1170	Lozhkin (1987)
Faddeyevskiy	GIN-8245	32,000 ± 280	this study
Faddeyevskiy	GIN-8226	31,400 ± 300	Sulerzhitsky and Romanenko (1997)
Faddeyevskiy	GIN-8260	29,700 ± 250	Sulerzhitsky and Romanenko (1997)
Faddeyevskiy	GIN-4330	29,100 ± 400	Sulerzhitsky (1995)
Kotel'nyy	LU-1791	29,020 ± 190	Makeyev et al. (1989)
Faddeyevskiy	GIN-8225	28,650 ± 350	this study
Faddeyevskiy	GIN-4710	28,000 ± 200	Sulerzhitsky (1995)
Faddeyevskiy	GIN-8224	27,100 ± 300	Sulerzhitsky and Romanenko (1997)
Faddeyevskiy	GIN-4710b	25,800 ± 200	Sulerzhitsky (1995)
Faddeyevskiy	GIN-8232	25,540 ± 170	Sulerzhitsky and Romanenko (1997)
Faddeyevskiy	GIN-8246	25,200 ± 180	Sulerzhitsky and Romanenko (1997)
Faddeyevskiy	GIN-8227	25,180 ± 150	Sulerzhitsky and Romanenko (1997)
Faddeyevskiy	GIN-8244	23,940 ± 150	Sulerzhitsky and Romanenko (1997)
Faddeyevskiy	GIN-5760	20,900 ± 100	Sulerzhitsky (1995)
Kotel'nyy	LU-1790	19,900 ± 110	Makeyev et al. (1989)
Faddeyevskiy	GIN-8229	18,500 ± 120	Sulerzhitsky and Romanenko (1997)
Kotel'nyy	LU-1671	15,420 ± 110	Makeyev et al. (1989)
Kotel'nyy	GIN-8230	13,700 ± 100	Sulerzhitsky and Romanenko (1997)
Bennett	LU-2096	12,590 ± 310	Verkulich et al. (1989)

Similar changes in the pollen spectra and similar contents of the upper 30 cm of the Holocene spectra are recorded in the Late Pleistocene-Holocene section from Sverdrup Island (Andreev et al., 1997). We propose that the upper 20 cm of the Faddeyevskiy Island section, with low pollen concentration and an increase in long-distance transported pollen taxa, also has a Holocene age and is probably eolian in origin.

One possible explanation of the difference between the diagrams on Figures 4 and 5 may be associated with differences in the pollen processing methods. The comparison of the results of the two techniques for pollen preparation shows that pollen preservation generally was better by the heavy liquid separation method, although samples chemically digested have more pollen and were cleaner and easier to count because of fewer mineral particles. The comparison also shows the lack of some pollen types such as *Juniperus*, *Papaveraceae*, *Scrophulariaceae*, and *Ephedra* in the spectra prepared by the chemical digestion method (Fig. 4). Spores of green mosses (Bryales) are more abundant in the spectra prepared by the heavy liquid separation method (Fig. 5), and the indeterminable pollen grains are more numerous in the pollen spectra of the chemical digestion method (Fig. 4).

The numerous poorly preserved tricolpate grains may belong to *Artemisia*, but the lack of surface sculpture on the grains does not allow more precise identification.

The differences in percentage values of the Poaceae and the Cyperaceae between the two diagrams may be partially due to the different portions of the sediment sample received by each laboratory, as these herbaceous families can vary in their abundances on very local scales. To compare our results with pollen data published by Russian investigators, the pollen data prepared by the heavy liquid separation method is preferred, because most Russian laboratories use this method.

The published pollen data from Kotel'nyy Island with similar radiocarbon ages 28,640 ± 700 yr BP (LU-1604) from section No. 3 and 28,410 ± 210 yr BP (LU-1751) from Balyktakh River section (Makeyev et al., 1989) show similar pollen spectra with significant amounts (up to 20–30%) of *Artemisia*, Poaceae, and Cyperaceae. Pollen spectra from peat dated to 29,750 ± 1100 yr BP (MAG-144) and 28,220 ± 1000 yr BP (MAG-174) from the northwestern coast of Kotel'nyy Island (Lozhkin, 1977) also show the dominance of herb taxa with significant amounts (up to 15%) of *Betula nana* and *Salix* pollen. The identified seeds belong to *Carex*, *Eriophorum*,

TABLE 4
Radiocarbon dated Bison priscus remains from Novosibirskie Islands

Location	Lab Number	Age	Source
Kotel'nyy	GIN-8253	43,400 ± 2200	Sulerzhitsky and Romanenko (1997)
Faddeyevskiy	GIN-8231	33,100 ± 320	Sulerzhitsky and Romanenko (1997)
Faddeyevskiy	GIN-8228	32,200 ± 600	Sulerzhitsky and Romanenko (1997)
Bel'kovskiy	GIN-8222	30,500 ± 400	Sulerzhitsky and Romanenko (1997)
Faddeyevskiy	GIN-4329	26,100 ± 300	Sulerzhitsky and Romanenko (1997)

and Poaceae. Poaceae, Cyperaceae, and *Artemisia* dominate pollen spectra from Bennett Island radiocarbon dated to 43,000–26,000 yr BP (Makeyev et al., 1992). The upper part of an undated pollen diagram from Reshetnikovaya River, Kotel'nyy Island (Alekseev, 1997) is very similar to our diagram and may reflect a similar environment and age.

Our determinable macrofossil remains belong mostly to *Carex* and green mosses (Fig. 3). *Carex* species were reported to be absent in the modern flora of Faddeyevskiy Island (Mikhailov, 1963). Three widely separated colonies of *C. stans* were founded recently in the vicinity of the site (Jónsdóttir et al., 1999). The other nearest sites with *C. stans* is situated on the southern coast of Kotel'nyy Island (Hultén and Fries, 1986). Several other *Carex* species (*C. bigelowii*, *C. ursina*, *C. ramen-skii*) occur on Bol'shoi Lyakhovskiy Island (Hultén and Fries, 1986; Ukraintseva et al., 1989).

The genetic analysis of *C. stans* genets from Faddeyevskiy Island indicates that they are not closely related (Jónsdóttir et al., 1999). Their age ranged from 18 to 108 yr. The age of two *C. ensifolia* ssp. *arctisibirica* clones from northern Taymyr was estimated to be between 2000 and 3000 yr (Jónsdóttir et al., 1999). Only one plant from these *C. stans* genets was flowering during the 1994 summer (Jónsdóttir, pers. comm., 1999). This suggests that *Carex* species may have no sexual reproduction for hundreds or thousands of years, and they are, probably, relicts from previous, more climatically favorable times. Modern plant ecological studies in the Canadian Arctic Islands by Edlund (1983, 1986); Edlund and Alt (1989) have shown that the northern limit of *Carex* species distribution is well correlated with the 4°C July isotherm. The numerous *Carex* remains and pollen in our section suggest that the summer temperature was at least 4°C during the interval of deposition, indicating a warming of 2°C compared with today.

This suggestion that the summer climate was warmer in this region during the Kargian interstadial corresponds well with the interpretations from other numerous pollen, macrofossil, and ¹⁴C data from the adjacent areas of Siberia (Arkhipov, 1984; Isayeva, 1984; Arkhipov and Volkova, 1995) showing spruce and birch distribution northward during the Kargian interval. *Artemisia*, Poaceae, and other herb pollen are also abundant in the pollen spectra. Radiocarbon dates obtained elsewhere for the interval are similar to ours (Table 2).

Sea level on the East Siberian shelf was significantly (up to 130 m at the Last Glacial maximum) lower than modern during the Late Pleistocene and the Novosibirskiy Ostrova archipelago became a part of the Eurasian continent (Fartyshev, 1993; Alekseev, 1997; Pavlidis et al., 1997; Sher, 1997). Our pollen, plant macrofossil, and radiocarbon data do not support the hypotheses that Faddeyevskiy Island was covered either by the ice (Grosswald, 1998) or by the sea water (Zagorskaya, 1958; Reinin and Kim, 1982) at 43,000–25,000 yr BP. We also doubt that ice covered this area after this interval, 43,000–25,000 yr BP, because of dated records from the Last Glacial Maximum to the Holocene on adjacent Kotel'nyy Island (Makeyev et al., 1989).

Poaceae, Cyperaceae, and *Artemisia* communities dominated in the area of the archipelago during the Late Pleistocene. The productivity of these communities was high enough to feed a population of grazing mammals. The numerous mammoth (*Mammuthus primigenius*) remains from Faddeyevskiy Island that have been collected in a 5 km vicinity of the site were radiocarbon dated to 36,700–18,500 yr BP (Table 3). The only few mammoth remains from Kotel'nyy and Bennett Islands are younger than Faddeyevskiy mammoths (Table 3). Rare bison (*Bison priscus*) remains from Faddeyevskiy and Bel'kovskiy Is-

lands also belong to the same time interval except one that is 10,000 yr older than the others (Table 4). Two horse remains (*Equus lenensis*) were radiocarbon dated to 29,100 ± 400 yr BP (GIN-4330) from Faddeyevskiy Island and 19,100 ± 120 yr BP (GIN-8252) from Kotel'nyy Island. Only muskox (*Ovibos moschatus*) remains from the Kotel'nyy Island were dated to 10,7500 ± 90 yr BP (LU-1666).

Conclusions

(1) A continuous clayey, sand and peat section with pollen and radiocarbon data from Faddeyevskiy Island indicates that a vegetated landscape existed between approximately 32,000 to 25,000 yr ago. There is no evidence that the hypothetical Pan-arctic Ice Sheet existed in this area from 43,000 to 25,000 yr ago. There is also no evidence that it existed on the island during the Last Glacial Maximum or Holocene.

(2) Poaceae, Cyperaceae, and *Artemisia* communities dominated over the expanded northward Eurasian continent with lowered sea level. The productivity of these communities was high enough to support the mammoths, bison, and horses, which grazed on graminoids.

(3) The numerous *Carex* remains in our section suggest that the mean summer temperature was at least 2°C warmer than today during the Kargian (Boutellier) interstadial on the island.

(4) A comparison of pollen results using the heavy liquid separation method and the chemical digestion method suggests that pollen preservation is generally better in the samples processed using the heavy liquid separation method, but samples are easier to count using the chemical digestion method, because of fewer remaining mineral particles.

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